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MEMORANDUM**

REPORT NO. 53894

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# SIMULATION TEST REPORT FOR MDA EXTERNAL MOBILITY AIDS EVALUATION

By Space Simulation and Experiments Office  
Manufacturing Engineering Laboratory

September 12, 1969



**NASA**

*George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama*

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SPACE SIMULATION AND EXPERIMENTS OFFICE  
SIMULATION ENGINEERING SECTION

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#### ABSTRACT

This document describes a neutral buoyancy simulation for evaluating the Multiple Docking Adapter (MDA) external mobility aids. The over-all objective of this test was to perform a human factors evaluation of the complete MDA external handrail system.

Subjective and objective data obtained from the test subjects indicated that the handrail system was usable. However, additional handrails in several strategically located areas, especially around the conical section, would greatly aid an astronaut in making the necessary translations. All docking ports and scientific airlocks could be reached using the handrails and work could be performed at these areas with the aid of tethers.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## ACKNOWLEDGMENT

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NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

SIMULATION TEST REPORT FOR MDA EXTERNAL MOBILITY AIDS EVALUATION

BY

SPACE SIMULATION AND EXPERIMENTS OFFICE  
SIMULATION ENGINEERING SECTION

MANUFACTURING ENGINEERING LABORATORY  
RESEARCH AND DEVELOPMENT OPERATIONS

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SIMULATION ENGINEERING SECTION

SUMMARY

The objective of this test was to perform a human factors evaluation of the MDA external hand rails. Specific tasks were to determine maximum reach envelopes over entire mockup, to perform timed runs between predetermined points on the surface of the mockup and to locate tether attach points for performing inspection and repair around each docking port and scientific airlock.

Subjective and objective data obtained from the test subjects indicated that the handrail system was usable. Testing revealed, however, that additional handrails placed in strategically located areas would greatly aid an astronaut in the necessary translations.

Translations to tether attach points chosen for performing inspection and repair at the docking ports and scientific airlocks could be made using the present handrail system.

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## INTRODUCTION

The Multiple Docking Adapter (MDA) is equipped with a set of external longitudinal and circumferential handrails provided with a tether attachment system for use by astronauts as mobility and stability aids during extra-vehicular activities (EVA). The design and location of these handrails should provide sufficient mobility to enable an astronaut to translate across the MDA for ATM film retrieval, to perform a general hull inspection, to inspect all docking ports, and to reach all scientific airlocks. In addition, the handrails and tether attachment system should enable the astronaut to perform required tasks such as general repair and maintenance of the MDA hull. The objective of this test was to perform a human factors evaluation of these handrails.

Testing was conducted in the 25-foot neutral buoyancy tank of the Manufacturing Engineering Laboratory.

## SIMULATION HARDWARE

A complete MDA neutral buoyancy mockup with supporting stands was placed in a horizontal position in the 25-foot neutral buoyancy tank. The mockup was oriented so that docking port number IV was turned toward the floor of the tank and the aft section of the mockup was turned toward the vent board control panel. (Standard Gemini waist tethers were used for determining reach limits at the docking ports and scientific airlocks).

In addition, a diver to manage the subject's umbilical lines from a location simulating the airlock module EVA hatch was used.

## SIMULATION TECHNIQUES

Each test subject received the same tape recorded briefing immediately before donning the pressure suit. Engineering drawings and pictorial illustrations of the mockup were used to explain each task. A systematically randomized order of task presentation to each subject was used according to Table I. Subject debriefings were held after the subject had finished testing. Descriptions of each task is presented below.

## TASK 1 - Translation Across MDA

Beginning at the aft MDA circumferential handrail at a point  $45^{\circ}$  between docking ports 1 and 4, translate in a straight line to the axial docking, Figure 1.

## TASK 2 - Reach Determination

Translate along each handrail placing spring clips at farthest point possible in each direction, Figure 2.

## TASK 3 - Access to Scientific Airlocks and Docking Ports

a. Locate optimum tether attach points for performing repair operations at each scientific airlock. Place spring clips at maximum reach points, Figure 3.

b. Locate optimum tether attach points for performing inspection and repair around complete circumference of each docking port. Place spring clips at maximum reach points around docking ports, Figures 4 and 5.

## TASK 4 - Translation Around Conical Section

Beginning on the outer end of the conical handrail between docking ports 1 and 4, proceed radially inward to axial port, translate  $360^{\circ}$  around port and return to starting position, Figures 6, 7, and 8.

## DATA GATHERING

a. Each task was timed and the test subjects' comments were recorded. Optimum tether attachment locations and measurements of each subject's reach envelop were recorded. Test subject debriefings were recorded on tape and hand written evaluation forms were completed.

b. The test engineer monitored the test viewing a closed circuit television with the camera located under water. Selected events of the monitoring were recorded on video tape.

c. Electronic communications were maintained between the

test engineer, test subject, and support personnel.

d. Motion and still photographic coverage of selected tasks was provided for detailed analysis.

e. A continuous recording of the subject's heart rate was maintained during testing.

A presentation of the data obtained is given in the Tables II and III.

## CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on test subjects' comments and observations made by the test conductor and support personnel.

### TASK 1 - Translation Across MDA

The supporting stands prevented translating in a straight line to the axial docking port from the aft MDA circumferential handrail as called for in Task 1. However, observations indicate that an extension of the longitudinal handrail beyond the forward circumferential handrail as shown in Figure 9 would aid the astronaut in making the necessary translation.

### TASK 2 - Reach Determination

The handrails were of a convenient size and shape and were located an acceptable distance from the surface of the MDA wall. The handrails alone provided enough stability for maximum reach. Since translations along each handrail were performed in a random order, the umbilical line had a tendency to get caught on the docking sights and other protrusions on the mockup. Reach measurements are shown in Table II.

### TASK 3a - Access to Scientific Airlocks

Access to the scientific airlock area could be made using a single set of tether points. Due to each airlock area being similar, only one airlock was investigated.

### **TASK 3b - Access to Docking Ports**

The docking ports were found to be slightly too large for easy 360° access. It was also noticed that downward reach below the tether points was limited because of the inability to bend the head and waist in the pressure suit. Test data indicates that four tether attach points equally spaced on the docking port rims would provide easy access to all areas, Figure 10.

### **TASK 4 - Translation Around Conical Section**

Testing revealed that for optimum ease in translation around the conical section, additional handrails as shown in Figure 11 are needed.

The only obstacle encountered in translating around the port was the docking sight. Due to its position, the subject had to translate over the sight as shown in Figure 8 in making the required translation. After the translation had been completed, the umbilical was found to have become wrapped around the axial docking port.

**TABLE I**  
**ORDER OF TESTING**  
**MDA EXTERNAL MOBILITY AIDS EVALUATION**

<u>RUN</u>	<u>TASK</u>	<u>SUBJECT</u>
1	3	A
2	1	A
3	2	A
4	4	A
5	2	A
6	4	A
7	1	A
8	3	A
9	4	B
10	3	B
11	2	B
12	1	B
13	4	B
14	2	B
15	3	B
16	1	B
17	4	C
18	2	C
19	1	C
20	3	C
21	2	C
22	4	C
23	1	C
24	3	C
25	1	D
26	2	D
27	3	D
28	4	D
29	2	D
30	3	D
31	4	D
32	1	D

TABLE II  
MAXIMUM REACH DISTANCES USING MDA  
EXTERNAL HANDRAIL SYSTEMS  
(Meters)

Subject	Trail No.	Aft Circumferential Handrail	Aft Longitudinal Handrail	Aft Circumferential Handrail	Conical Handrails				Longitudinal Handrail Right/Left
		Right/Left	Right/Left	Right/Left	# 1 Right/ Left	# 2 Right/ Left	# 3 Right/ Left	# 4 Right/ Left	
1	1	1.24/ -	1.24/1.21	1.24/1.19					1.24/1.21
1	2	1.32/1.14	1.06/1.01	1.27/1.16					1.16/1.32
2	1	1.27/ -	.96/1.11	1.04/ -	1.06/ 1.27	0.58/ 1.06	-/1.14	1.08/-	1.19/0.89
2	2	1.16/ -		1.21/1.21	1.29/ 0.91	1.34/ 0.91	-/1.09	1.16/-	1.37/0.89
3	1	1.24/ -	1.16/1.24	1.32/1.19	0.96/ 0.89	0.88/ 0.91	-/0.99	1.21/-	- /1.24
3	2	1.16/ -	1.10/1.16	1.14/0.99	1.14/ 1.32	1.21/ 1.21	-/1.16	1.29/-	- /1.44
4	1	1.16/ -	1.29/1.16	1.14/1.14	1.09/ 1.06	0.66/ 0.71	-/0.88	1.06/-	1.11/1.01
4	2	1.21/ -	1.04/1.06	1.16/1.01	2.05/ 2.08	-/0.48	-/0.76	0.76/-	-----

COMMENTS: Subject No. 1 performed tasks with mockup conical section positioned against tank wall.

This prevented access to the conical handrails.

TABLE III.

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

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Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Scientific Airlock	1	1	Previous data indicates that tethers should be located on circumferential handrail forward of docking port no. 3 approximately 0.71m (28 in.) apart.	----	----	Subject oriented with head toward forward section of mockup.
	1	2	Data not obtained.	----	----	-----
Docking Port No. 1	1	1	Right tether located on edge of docking port APP. - $232^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at forward end. Left tether located on circumferential handrail forward of docking port.	0.38/0.53 measured from port rim	0.35/0.15 measured from port rim	Subject's head oriented toward docking port no. 2.
Docking Port No. 1	1	2	Right tether located on edge of docking port APP. - $265^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at forward end. Left tether located on circumferential handrail forward of docking port.	0.68/1.42 measured from center of port	0.76/0.63 measured from center of port.	Subject's head oriented toward docking port no. 2.

TABLE III. (continued)

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Docking Port No. 3	1	1	Right tether located on circumferential handrail forward of docking port. Left tether located on port rim AAP $120^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at forward end.	0.71/0.27 measured from port rim	0.25/0.27 measured from port rim	Subject's head oriented toward docking port no. 2.
Docking Port No. 3	1	2	Right tether located approximately 0.10m. (4 in.) below circumferential handrail, 0.76m (30 in.) right of center longitudinal line. Left tether located on inside of port rim approximately $120^{\circ}$ from longitudinal line, $0^{\circ}$ at forward end.	0.91/0.71 measured from center of port	0.76/0.71 measured from center of port	Subject's head oriented toward docking port no. 2.
Scientific Airlock	2	1	Right tether located approximately 0.86m. (34 in.) right of circumferential handrail on center longitudinal line. Left tether located on circumferential handrail at intersection with longitudinal center line.	0.94/0.38 measured from center handrail	0.45/0.40 measured from center longitudinal line	Subject's head oriented toward docking port no. 2.
Scientific Airlock	2	2	Right tether located approximately 0.86m. (34 in.) right of circumferential handrail on center longitudinal line. Left tether located on circumferential handrail at intersection with longitudinal center line.	.86/1.06 measured from center handrail	-----	Subject's head oriented toward docking port no. 2.

TABLE III. (continued)

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TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Docking Port No. 1	2	1	Right tether located on port rim $187^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at forward end. Left tether located on port rim $353^{\circ}$ measured as above.	0.60/0.66 measured from port rim	0.40/0/30 measured from port rim	Subject's head oriented toward docking port No. 2.
Docking Port No. 1	2	2	Tethers located on port rim right - $212^{\circ}$ and left - $353^{\circ}$ , from longitudinal line through center of port, $0^{\circ}$ at forward end.	0.76/0.68 measured from port rim	0.33/0.38 measured from port rim	Subject's head oriented toward docking port No. 2.
Docking Port No. 3	2	1	Tethers located on port rim, right - $0^{\circ}$ , and left - $180^{\circ}$ , from longitudinal line through center of port, $0^{\circ}$ at forward end.	0.55/0.40 measured from port rim	0.40/- down reach to under-side of port rim	Subject's head oriented toward docking port No. 2.
Docking Port No. 3	2	2	Tethers located on port rim, right - $54^{\circ}$ , and left - $126^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at forward end.	0.73/0.53 measured from port rim	0.27/0.30 measured from port rim	Subject's head oriented toward docking port No. 2.

TABLE III. (continued)

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Axial Port	2	1	----- DATA NOT OBTAINED -----	-----	-----	-----
Axial Port	2	2	Tethers located on port rim, right $-27^{\circ}$ , and left $-153^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at port No. 1 side.	0.45/0.55 measured from port rim	0.28/0.30 measured from port rim	Subject's head oriented toward docking port No. 2.
Scientific Airlock	3	1	Right tether located 1.24m. (49 in.) forward of circumferential handrail. Left tether located on port rim $15^{\circ}$ from longitudinal line, through port, $0^{\circ}$ at forward end.	1.21/1.21 measured from center handrail	1.24/1.06 measured from long. line through center of Port No. 3	Subject's head oriented toward docking Port No. 2.
Scientific Airlock	3	2	Same as above except right tether located slightly below center longitudinal line.	1.39/1.11 measured as above	1.27/0.88 measured as above	Subject's head oriented toward docking Port No. 2.

TABLE III. (continued)

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
• FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Docking Port No. 1	3	1	Tethers located on port rim, right -190°, left 350° from longitudinal line through center of port, 0° at forward end.	0.78/0.88 measured from port rim	0.81/0.66 measured from port rim	Subject's head oriented toward docking port No. 2.
Docking Port No. 1	3	2	Tethers located on port rim, right -185°, left -355° from longitudinal line through center of port, 0° at forward end.	0.48/0.55 measured from port rim	0.94/0.55 measured from port rim	Subject's head oriented toward docking port No. 2.
Docking Port No. 3	3	1	Tethers located on port rim, right 15°, left -160° from longitudinal line through center of port, 0° at forward end.	1.24/1.24 measured from port rim	1.29/0.78 measured from port rim	Subject's head oriented toward docking port No. 2.
Docking Port No. 3	3	2	Tethers located on port rim, right 15°, left -160° from longitudinal line through center of port, 0° at forward end.	1.39/0.73 measured from port rim	1.12/0.60 measured from port rim	Subject's head oriented toward docking port No. 2.

TABLE III. (continued)

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Axial Port	3	1	Tethers located on port rim, right $-10^{\circ}$ , left $-153^{\circ}$ from center longitudinal line through port, $0^{\circ}$ at port No. 1 side.	0.81/0.58	1.14/0.96	Subject's head toward docking port No. 2.
Axial Port	3	2	Tethers located on port rim, right $-10^{\circ}$ , left $-153^{\circ}$ from center longitudinal line through port, $0^{\circ}$ at port No. 1 side.	0.58/0.55	1.11/0.71	Subject's head toward docking port No. 2.
Scientific Airlock	4	1	Right tether located 0.88m. (35 in.) forward of circumferential handrail on longitudinal line through center of port No. 3. Left tether located on circumferential handrail at intersection with longitudinal line through center of port No. 3.	1.01/0.45 measured from center handrail	1.14/1.06 measured from long. line	Subject's head toward docking port No. 2.
Scientific Airlock	4	2	---- DATA NOT OBTAINED ----	-----	-----	-----

TABLE III. (continued)

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

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Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Docking Port No. 1	4	1	Tethers located on port rim, right -190°, left -350° from longitudinal line through center of port.	0.55/0.50 measured from port rim	0.68/0.58 measured from port rim	Subject's head oriented toward port No. 2.
Docking Port No. 1	4	2	Tethers located on port rim, right -180°, left -0° from longitudinal line through center of port.	0.99/1.14	0.91/0.96	Subject's head oriented toward port No. 2.
Docking Port No. 3	4	1	Tethers located on port rim, right 0°, left 180° from longitudinal line through center of port.	0.78/0.58	0.76/0.86	Subject's head oriented toward port No. 2.
Docking Port No. 3	4	2	Tethers located on port rim, right 0°, left 180° from longitudinal line through center of port.	1.09/1.05	0.93/0.86	Subject's head oriented toward port No. 2.

TABLE III. (continued)

TETHER ATTACH POINT LOCATIONS AND MAXIMUM REACH LIMITS  
FOR MDA SCIENTIFIC AIRLOCKS AND DOCKING PORTS

Area	Subject	Trial No.	Tether Point Locations	Reach Limits (Meters)		Comments
				Right/Left	Top/Down	
Axial Port	4	1	Tethers located on port rim, right $-0^{\circ}$ , left $180^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at port No. 1 side.	0.58/0.33	0.83/0.45	Subject's head oriented toward port No. 2.
Axial Port	4	2	Tethers located on port rim, right $-0^{\circ}$ , left $180^{\circ}$ from longitudinal line through center of port, $0^{\circ}$ at port No. 1 side.	1.06/1.37	1.42/1.29	Subject's head oriented toward port No. 2.



FIGURE 1. SUBJECT TRANSLATING ALONG LONGITUDINAL HANDRAIL

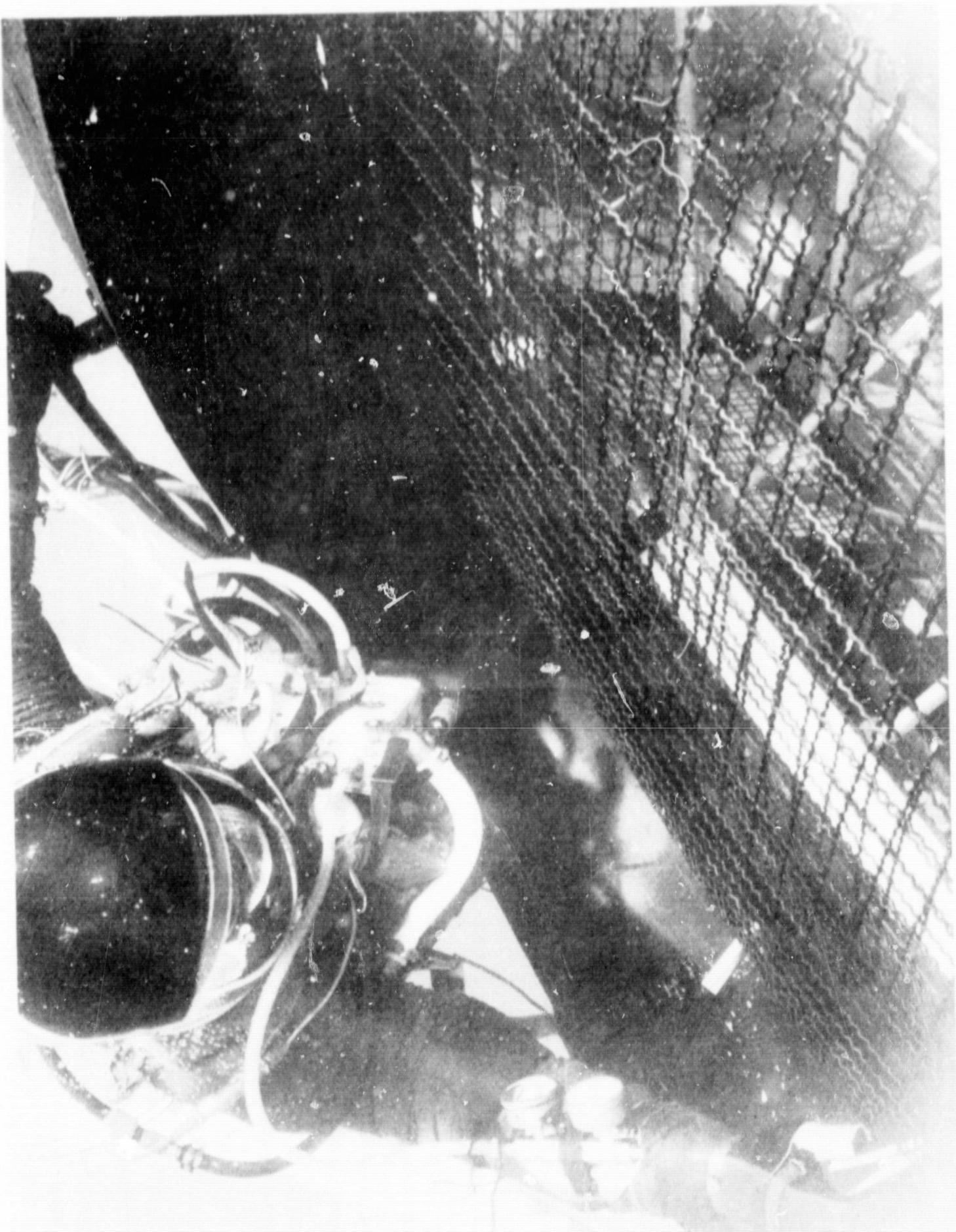


FIGURE 2. SUBJECT DETERMINING MAXIMUM REACH FROM CIRCUMFERENTIAL HANDRAIL



FIGURE 3. SUBJECT DETERMINING TETHER ATTACH POINTS FOR SCIENTIFIC AIRLOCK AREA



FIGURE 4. SUBJECT DETERMINING TETHER ATTACH POINTS FOR  
DOCKING PORT NO. 1



FIGURE 5. SUBJECT DETERMINING MAXIMUM REACH LIMITS  
FROM DOCKING PORT NO. 1



FIGURE 6. SUBJECT TRANSLATING TO AXIAL PORT



FIGURE 7. SUBJECT TRANSLATING 360° AROUND AXIAL PORT



FIGURE 8. SUBJECT TRANSLATING OVER DOCKING SIGHT DURING 360° TRANSLATION AROUND DOCKING PORT

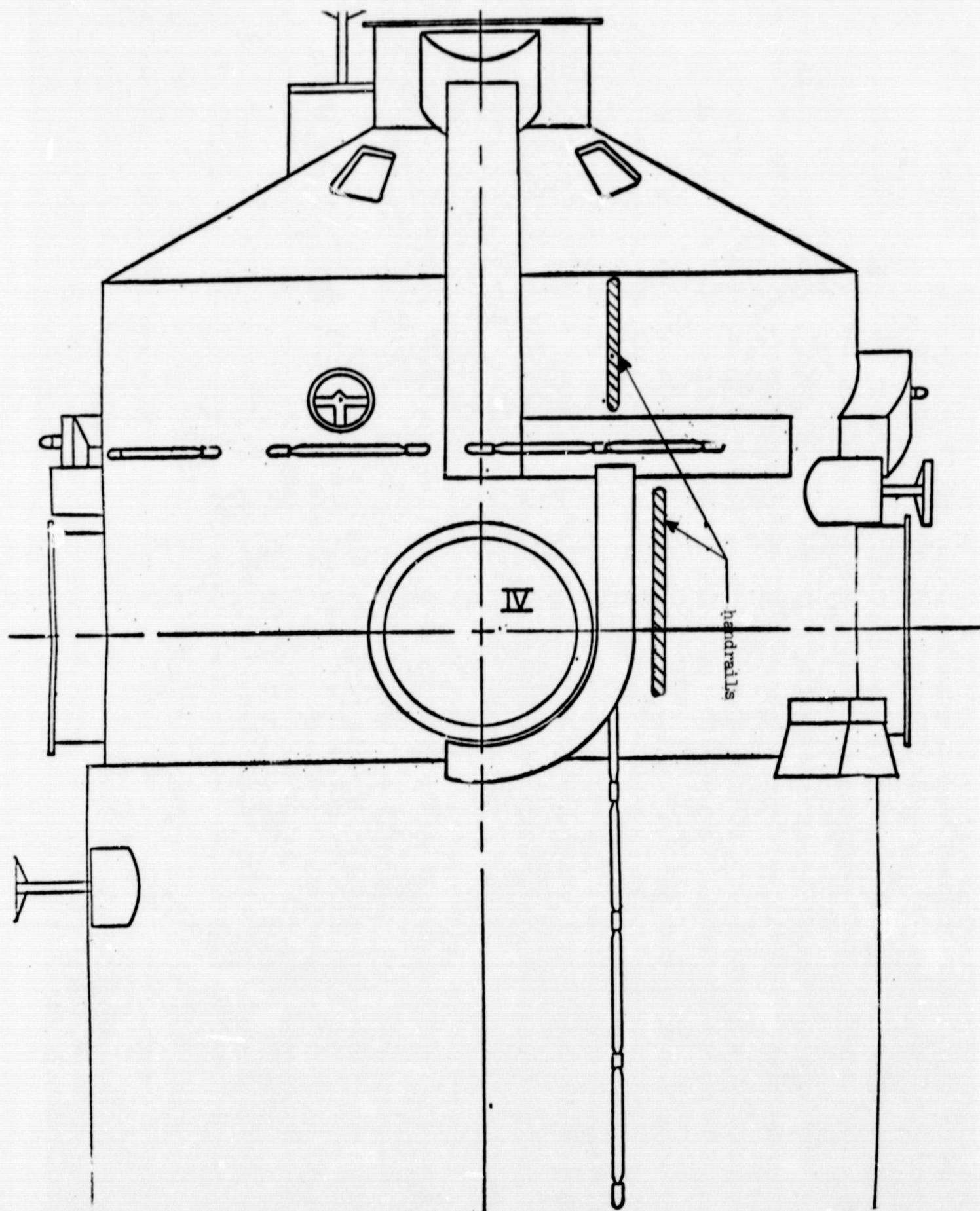


FIGURE 9. SUGGESTED HANDRAIL EXTENSION FOR LONGITUDINAL HANDRAIL

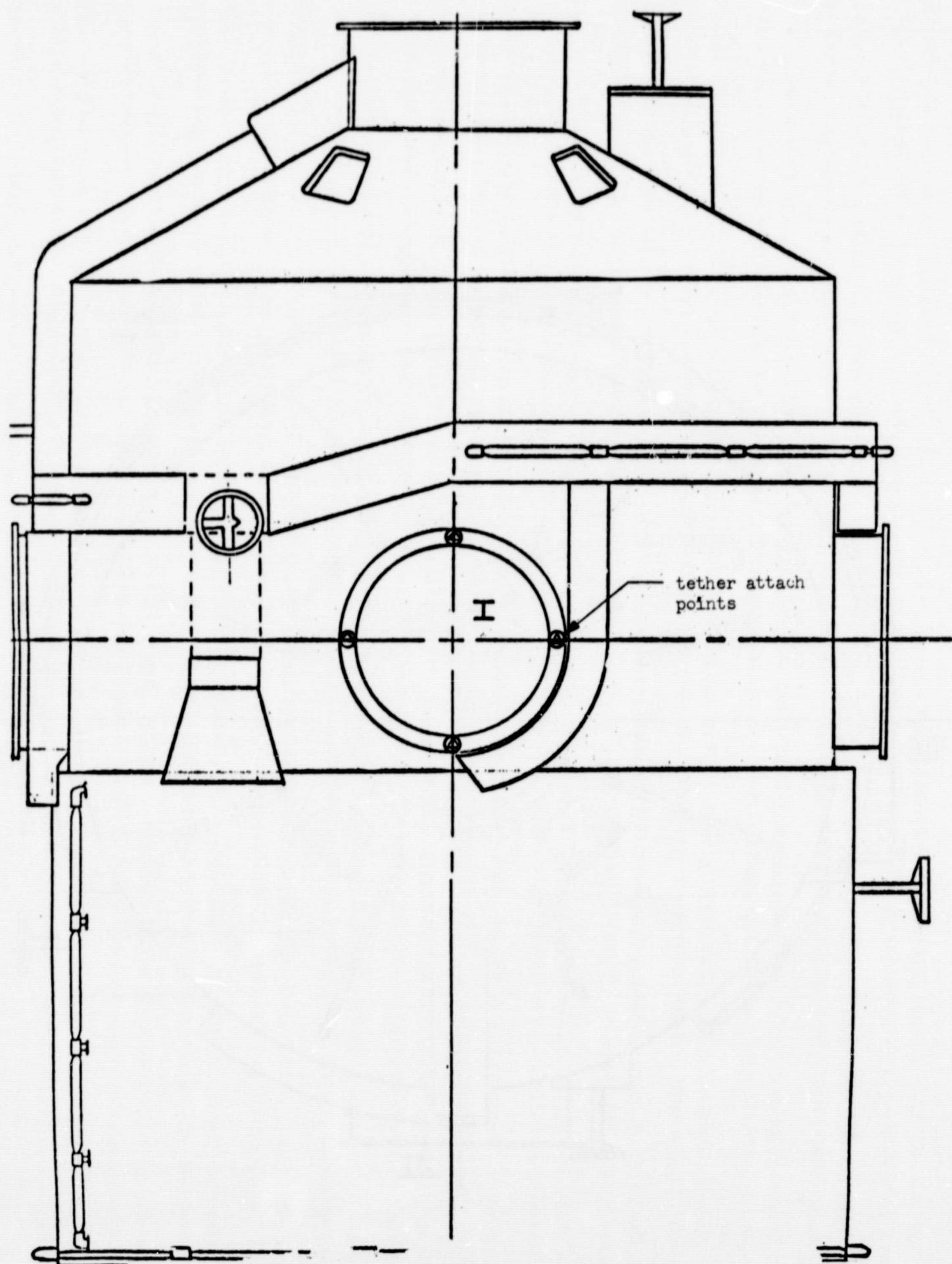


FIGURE 10. SUGGESTED TETHER ATTACH POINTS FOR DOCKING PORTS

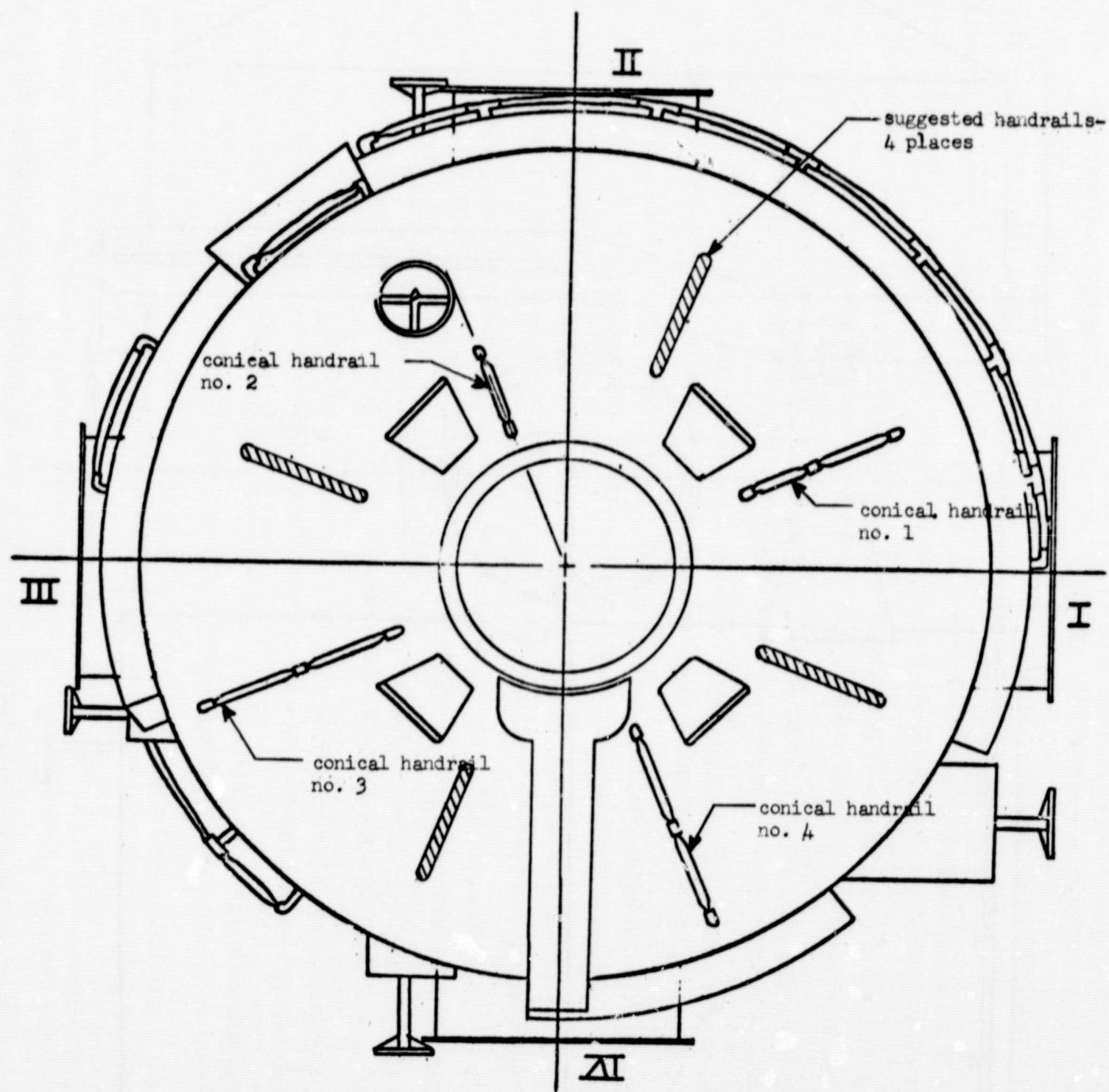


FIGURE 11. SUGGESTED HANDRAILS TO BE ADDED TO CONICAL SECTION